# THE LAKE GEORGE SENKUNGSFELD, A STUDY OF THE EVOLUTION OF LAKES GEORGE AND BATHURST, N.S.W.

By. T. Griffith Taylor, B.Sc., B.E., Assistant Demonstrator in Geology and Lecturer in Commercial Geography at the University of Sydney.

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Part i. Lake George.



## Part i. Lake George.

### i. Introduction.

The lakes of New South Wales are conspicuous by their rarity. Undoubtedly the most important, and perhaps the largest, is Lake George, which lies in the angle between the Southern and Cooma railway lines. It is 25 miles south-west of Goulburn, but is most accessible from Bungendore, on the Cooma line. With the exception of the meteorological investigations instituted by the late Mr. H. C. Russell, little research—certainly none of a physiographic nature—has been carried out in this district.

The following statement embodies the current opinion as to the lake's environment, and is in itself sufficient to indicate a very promising field of research on the lines of modern physiography. The quotation runs as follows:—"Lake George occupies . . . . the southern portion of a depression in the Cullarin Range, called the Lake George Basin, 490 square miles in extent, and (is) *the solitary example in the colony of a purely inland drainage area*, watered as it is by several small streams, but having no visible outlet."*

Paradoxical as it may sound, a lake is to a certain extent an *unnatural* natural feature. At any rate, especially in mountainous regions, its presence often implies abnormal conditions. Thus the great lakes of America are due to the somewhat erratic arrangement of the drifts of the Ice Age. The great lakes of Africa are due to a huge crustal rift. The small lakes of Kosciusko are geologically ephemeral, and the moraine barriers which dam back the waters are rapidly vanishing as the streams *cut down to base level*, which is indeed their "aim in life." Any complete interruption of a large drainage area, such as obtains in the case of the Lake George Basin, points to important late geological changes; which changes will, it is hoped, be clearly demonstrated in the succeeding account of the Lake George Senkungsfeld (*subsidence area*).

## ii. General Topography.

A reference to the stereogram (Plate viii.) will convey a clear idea of the topography of Lake George. The lake proper extends about 15 miles in a north and south direction, and may be closely compared in outline to a *bow* (variety Cupid's); the string symbolising the *straight*, *even* western shore, while the double-curved eastern boundary resembles the wooden bow. This contrast of

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* Geography of New South Wales, 3rd Ed., by J. M. Taylor, p.81. (The italics are mine. —T.G.T.).

boundary is of great importance in the physiography of the lake, so that the above analogy will perhaps be found of assistance.

At the northern extremity a series of gravel banks separate the lake from Murray's Lagoon, which latter at present (February, 1907) is a dry area about one mile in diameter covered thickly with rushes. Beyond this the country consists of a flat expanse extending towards Breadalbane. The Divide between the Wollondilly River system and the Lake George area is not well defined and seems to lie just north of the main Southern Railway.

On the eastern shore the lake outline is somewhat irregular. Ondyong Point, Rocky Point, Currandooley Point and Native Dog mark the spurs projecting from the Gourock Range into the lake (Plate vii.). In broad valleys between these spurs lie the streams which water Lake George; Murray's Creek (the name on the map, *Allianoyonyiga*, one is not surprised to find unknown in the district); Taylor's Creek at the foot of Governor's Hill, the most prominent landmark round Lake George; Deep Creek and Turallo Creek. It will be noticed that these creeks converge on the locality known as Geary's Gap (*vide* stereogram).

Reverting to the western shore, we are struck by the absolute dissimilarity. Standing at the level of the lake we seem to be confronted by a giant wall extending northwards for over twenty miles from the Molonglo Plain. No broad valley breaks its continuity. Indeed, to one cycling along the foot of the Cullarin Range, it seems unbroken by any definite gap, while for a large part it presents a steep face 500 feet high to the lake. From the opposite shore (Governor's Hill), however, one is able to see a well defined *gap* about half-way along the western shore where the old Southern Road crossed the Cullarin Range. This depression—Geary's Gap—was well known in the days before the railway, but is now practically unused by travellers. Less than two miles south of Geary's Gap a stream (Grove Creek) rushes down to the lake. Contrast its course with that of Taylor's Creek on the eastern shore. The latter stream flows through a broad valley, a mile or two wide, scooped out of the granite, and shows the even grade of a mature or senile type of river. The Grove

Creek is barely a mile long, yet descends nearly three hundred feet. Its course is interrupted by falls 25 feet high, and finally it emerges from a gorge, or miniature cañon, with steep sides 200 feet high. Evidently it is a stream which has barely reached the youthful stage. The hollows carved out of the slate bear witness to the violence of the stream upon occasions, but for the greater part of the year it dwindles to a succession of rocky pools.

Travelling south, we arrive at a stream of some importance, the Molonglo River, about 12 miles south of the lake. This cuts across the Cullarin Range near Hoskin's Town (see Plate vii.). Suspecting that this river might have participated in the abnormalities characteristic of the Lake George Basin, I wrote to Mr. A. E. Tuckwell, of Hoskin's Town, who amply confirmed my anticipations, as the following extract will show:—"The Molonglo River *leaves the flat country* 5 miles to the west of Hoskin's Town Public School, and flows through *a narrow gorge* bounded by hills, some of them approaching mountains."

Anyone who has enjoyed a trip up the Nepean from Penrith to Mulgoa, will remember that, at the latter place, the river leaves the plains and abruptly enters a steep gorge. The Nepean Gorge is due to the river *gradually eating down* its bed as the Blue Mountain scarp was elevated. This is the key to the Lake George problem. The Molonglo River (see Plate viii., at the lower rim of the model) has kept to its bed in spite of the fact that its basin at one period of its existence experienced a differential movement, the upstream portion sinking with respect to the lower. Subsequently (28th March, 1907) I visited the Molonglo Water-Gap and found that the river's course is concordant with the above account. Immediately at the entrance of the gorge, the slates and laminated quartzites are much crumpled and overfolded. This is the only locality where I observed such phenomena; the Silurian (?) strata, for the most part, being folded on a *large* scale and not crumpled locally. This local action occurring just at the plane where upthrow and downthrow meet, would seem to suggest that some considerable secondary folding has been superimposed on the ancient Silurian synclines and anticlines. In fact here we may have positive evidence of the *Tertiary folding* into which the Cullarin or Lake George Fault has passed at its southern extremity.

### iii. The Cullarin Fault.

Leaving the description of the central—true lake-bottom—portion of the area to a later section, an explanation of the above phenomena, together with further evidence of a convincing nature will now be given. To anyone versed in geology, the thirty mile scarp constituting the Cullarin Range, especially when seen from an elevation at some distance, is inexplicable except as a fault scarp. Probably the scarp originated as a succession of small faults along the same plane, extending over a considerable period. Indeed the northern scarp is much more abrupt (having slopes reaching 45° in places) than the southern, Bungendore, portion. One may reasonably suppose that the tectonic action was more vigorous to the north and extended to a later geological period.

The geological features of the district are comparatively simple. With the exception of a few square miles of country near Governor's Hill (east of the Lake) where there is an interesting series of eruptive rocks,* the rock consists of slates and phyllites having a fairly uniform strike nearly north and south, the dip being nearly vertical sometimes to the west (Geary's Gap 70°) or again to the east (Native Dog 63°). On the eastern shore these rocks outcrop within the edge of the Lake, but on the west the slates end abruptly at the silt. A certain amount of talus from the hills is distributed at intervals along the western shore, but wells

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* This area is roughly indicated on the map (Plate vii.). Rocks of two types are present. Granite of a somewhat porphyritic nature, showing some evidence of regional metamorphism in the shape of banded felspars, etc., is fringed (see fig. 1) by a complex series of basic and ultrabasic rocks ranging from dolerite to picrites and serpentines. The latter are coated with concentric layers of secondary lime (travertine). This outcrop would seem to be worthy of investigation by geologists interested in differentiation.

dug in the vicinity seem to show that this material is in many cases superficial, and lies over the silt and clay which occupies the lake bed (see Section, fig. 1).

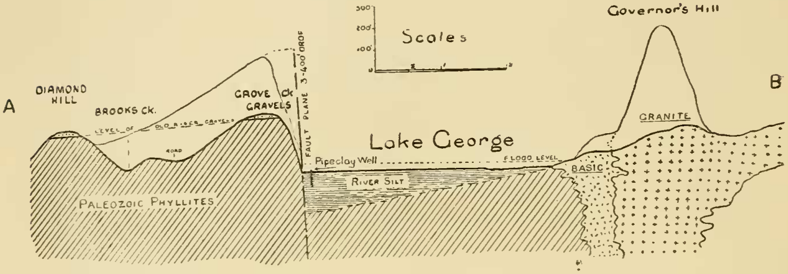


Fig. 1.—Section AB (see Plate vii.) showing the Senkungsfeld and Fault Plane, also the High-level Gravels of the old outlet.

Assuming a *strike fault* as being the cause of Lake George, let us endeavour to reconstruct the topography of the country before the faulting. If the Lake George Basin were raised some 300 feet, the four creeks (Murray, Taylor, Deep and Turallo) would evidently unite into one river, which would flow towards the west and ultimately reach the Yass River above Gundaroo. Some trace of this old river (which we may conveniently call *Lake George River*) should remain in the form of an old valley, which, owing to later erosion on a different system of drainage, should appear much like a *water-gap*. In addition, it is not too much to expect that some of the old river boulders shall have remained, no longer necessarily in the *lowest* portions of the area of elevation (since the latter has been since modified by later stream-action). If, as is often the case, the fault has diminished in extent towards its extremities, we may expect that some (antecedent) river-systems have been able to keep their old path in spite of tectonic obstructions.

All these phenomena are abundantly shown in the Lake George area. Ascending the steep hill face, 300 yards north of Grove Creek, and 1½ miles south of the *present* lowest point of the Cullarin Range, a deposit of elevated river-gravels is reached.

About 500 yards due west from the Lake at this point one reaches the top of the ridge and arrives at a cluster of mine-shafts varying in depth from 5 to 40 feet. This patch of gravel is oval in shape, with the long axis W.N.W. and half-a-mile long (see Plate vii.). The shafts have been abandoned for several years and do not seem to have yielded much gold. However, they enabled one to make the rough geological section shown at B, fig. 2. The boulders were shaped much like a potato for the most part, and distributed through a deep red clay. They varied in size from a few inches to 2 feet in diameter. The junction of the boulders and slates was marked by a very hard layer of pebbles (3″) cemented by a ferruginous material. At the centre of the field, pipeclay was struck at lower levels.

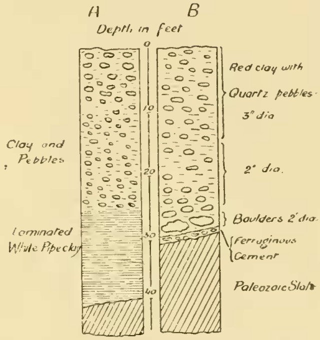


Fig. 2.—Vertical sections in alluvial shafts. A. Central portion of elevated gravels; Diamond Hill. B. Southern margin of elevated gravels; Grove Creek.

Continuing the traverse towards the west (see Section, fig. 1) slates and quartz reefs were crossed. Brooke's Creek, which flows through a rather narrow valley, with steep bluffs (evidence of youth and uplift) was reached. This creek, which had a fine flow of water (February, 1907), is probably an old tributary of the "Lake George River," which has been *revived* by the slight uplift which probably accompanied the senkungsfeld. Enquiring for elevated gravels, I was informed of the Diamond Hill Diggings, which lie half-a-mile from Brooke's Creek in the sharp bend it makes to the west (see Plate vii.). Here occurs another patch of gravels, practically identical in form with that at Grove Creek, with the same direction, W.N.W. The area is about 200 × 100 yards, and the lower 15 feet of the deposit (see A, fig. 2) consists of a laminated pipeclay. Here, again, the boulders consist chiefly of rounded quartz. Returning to the lake-bed itself, just at the mouth of Grove Creek, a well has been sunk thirty feet into the silt. The dump consists largely of pipeclay identical in appearance with that from the shafts *nearly 300 feet higher* on the elevated alluvials. I was informed that boulders of a similar nature to those found at Diamond Hill were removed, but the clay had covered over the early dumpings.

We have no data sufficient to estimate the length and drop of this fault. It extends for more than twenty miles from Collector to Bungendore. Beyond the latter, as the *Molonglo* has cut through the scarp (see page 334), the fault was not so extensive, or the movement may have developed merely as a fold. It is a matter of great difficulty to detect Tertiary foldings superimposed on Palæozoic anticlines, but the river-development would seem to suggest that such faulting or folding has occurred near Molonglo. North of Molonglo River the streams flowing from the west are obsequent, and flow to the lake with short steep beds in narrow gorges. Here, undoubtedly, a fault on a large scale has taken place, and totally altered the drainage system, the tributaries of "Lake George River" being *betrunked* much as are those flowing into Port Phillip (Gregory).

Since the river-gravels at Grove Creek are elevated 270 feet above the lake-bed, we require a *minimum* drop of 270 feet. The well sunk in the silt adds 30 feet. This well by no means reached rock bottom. There is an opinion, shared by the expert local engineer, Mr. Glover, that the silt is 100 or 200 feet deep on the western shore of the Lake. The lesser figure agrees closely with the slope of the line joining the Grove Creek and Diamond Hill gravels (see Fig. 1). Hence it seems legitimate to place the fault drop at about *370 feet* at this locality (Geary's Gap).

Comparing this with the Kurrajong Fault, it would appear to be on a somewhat similar scale. The fault, as described by Professor David,* extends about twenty miles, and has a drop of

* "An important Geological Fault at Kurrajong Heights, N. S. Wales." Journ. Proc. Roy. Soc. N. S. Wales, 1902.

about 423 feet at the maximum point. It has not, however, led to the formation of any area of internal drainage as is the case at Lake George.

iv. Topographical Changes since the Faulting.

These fall into two classes, (a) those due to erosion, (b) those due to aggradation. The former have affected the positive forms (hills, &c.); while the latter have tended to fill up the negative land forms, in this case the bed of Lake George. The more or less sharp edge left at the close of the faulting has been gnawed away; but, as noted previously, many slopes of 45° can still be obtained at the northern end. This is a remarkably steep face for a continuous range, and points to the comparatively recent character of the subsidence. It may be estimated that a wedge-shaped slice of slate some twenty miles long, with a base about 300 yards wide, and a depth of 500 feet has been removed by erosion of the scarp. This wedge of eroded material might be made the basis of a calculation as to the age of the fault, but a much more promising method is amplified in a later section (vi.).

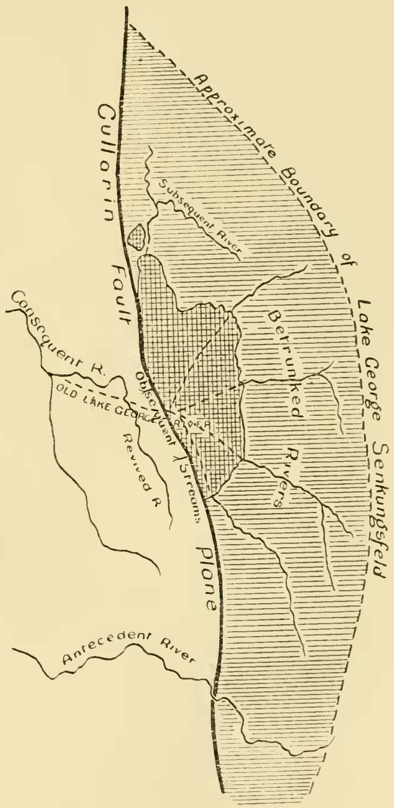


Fig. 3.—Map showing evolution of the river-system in the Lake George area. For topographical names, see text and Plate vii. The area of subsidence is hatched.

The river-courses have been largely influenced by the fault. The Molonglo River being situated toward the southern extremity of the fault plane—where the latter was probably of much smaller dimensions, possibly only a fold—has defied the tectonic changes to alter its course, and it has eroded a deep gorge in the "uplift" side of the fault, and, its course being independent of present land contours, the stream is of the *antecedent* type (see Fig.3).

The small streams running down the face of the fault are typically *obsequent*, since they flow directly against the main slope of the country (which normally falls to the west). Grove Creek, Geary's Creek, &c., are of this character. As pointed out previously, the small rivers of the east coast of the Lake (Murray, Taylor, Deep Creek, &c.) were originally united, but their lower portions are now buried deep in the silt, and therefore they belong to the *betrunked* class of rivers. Brooke's Creek for much of its path flows through fairly deep gorges. This tends to support the theory that the western side of the fault has participated slightly in the earth-movements. Not unusually the scarp of a large fault has been elevated absolutely as well as relatively, and this would appear to be the case at Lake George. If so, then Brooke's Creek is a *revived* river. Yass River, flowing normally to the west, may be taken as a specimen of a *consequent* river. To the north of the Lake, the Currawang Creek flows north-west for most of its course, and then bends back to the south. It is extremely probable that this creek originally formed portion of the Wollondilly system, but, owing to the depression of Lake George, it has been captured by the Winderadeen Creek, and now runs into Lake George. As this deviation is due to causes that acted subsequently to the establishment of the main slope, this river may be said to be *subsequent*. In brief, in this comparatively small area we have examples of the six main river-types, consequent (*Yass*), obsequent (*Grove Creek*), subsequent (*Currawang*), betrunked (*Murray, &c.*), revived (*Brooke's*), and antecedent (*Molonglo*). Finally, the "Lake George" is a splendid example of what has been termed a *dead* river.

Reverting at this somewhat late stage to the condition of the actual bed of the Lake, the latter is at present in a very favourable state for examination, since—with the exception of the small patch in the S.E. corner shown in Plate vii.—it is now (February, 1907) absolutely dry. The bed therefore presents a unique appearance. A level plain, apparently as flat as a billiard table, extends for over 15 miles, unrelieved by any islets or undulations as is the case with Lake Bathurst. Indeed, the plain extends for over 30 miles without obstruction, which fact may have helped to determine the choice of Bungendore for the primary base-line in New South Wales. Mr. Glover* has carried out levelling operations, and finds the south-central portion to have a fall of 4 feet in the mile, while to the north the slope is less than 2 feet to the mile.

Such a dead level seems to corroborate the theory that Lake George never had an outlet since it was first formed. No evidence of any flood more than 30 feet deep can be traced as having occurred for many hundred years, while nearly 200 feet are necessary to provide an outlet north, west or south. Probably *since its inception* the Lake has been receiving silt which has gradually filled up its bed, and covered over all ancient irregularities. Near Grove Creek there is an isolated ridge of angular quartz grit about 150 feet long, 50 wide, and 5 feet high. This may represent a sort of *Nunatak* (to use a glacial term) projecting above the silt. It constitutes practically the only outcrop on the western shore. At either end of the Lake—near Murray's Lagoon and near Bungendore—there are extensive *gravel deposits.* The former extends for more than a mile around the southern border of Murray's Lagoon (see Plate vii.). It reminds one irresistibly of the clinker or *hurricane banks* of coral shingle on the Barrier Reef. There is the same steep slope to

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* "Notes upon Floods in Lake George," by H. C. Russell, B.A., F.R.S., &c., Journ. Proc. Roy. Soc. N. S. Wales, Dec., 1886. In this paper a full account of the levelling and contours of the Lake is given, together with the history of the Lake till 1886.

the water's edge, 30 feet high, at an angle of 26°. The same tongues project out behind to the leeward side (indicated in Plate vii.). Probably a like origin may be assigned to these gravel-banks. They are due, I think, to the action of the storms on the lake when the latter is full. The winds are confined by the gigantic wall of the fault scarp, and rush along the latter, driving forward the angular talus with which the scarp is littered. Gradually the angular fragments are rounded and collect at the ends of the Lake, in much the same way as on a coral reef the clinker gradually accumulates towards the lee side of such reef.

## v. Economic Aspect of the Senkungsfeld.

Little attention has hitherto been paid in Australia to the relation between physiography and economics, which fact may justify the following brief digression. In the first place mention may be made of the gold alluvial rendered available for human industry by the deviation of water from the old Lake George River. In 1860 there was a gold rush to Diamond Hill, then called the Brooke's Creek Gold Rush. From the numerous shafts sunk, as well as from the recollections of old residents, this would appear to have been fairly successful. Several years ago, a few diamonds were washed out of this same gravel, and hence the change of name. Grove Creek gravels do not seem to have been payable. The miners experienced great difficulty in cutting through the layer of ferruginous cement at the bottom of the gravels, and most of the claims were therefore abandoned. Now the old wives of the district use the pipeclay for whitening their hearths, without experiencing much curiosity as to how it got there.

The graph of Lake-variation is inserted (*vide* fig.4) to show the periods when Lake George really was a lake. Such were the years 1816-1830, 1852, 1864, 1874-1900. Since 1900 the Lake has been shrinking, and was practically dry in 1905. A local flood has practically no effect on the Lake. The dry silt acts as a huge sponge, and absorbs a covering of several inches of water, brought down by Deep Creek or some other feeder, in the course of a night. The conditions are eminently favourable for great evaporation. The wind will drive a layer of water several miles from

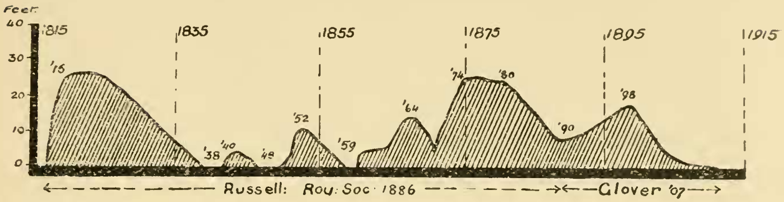


Fig. 4.—Variations in the level of Lake George, 1815-1907.

the actual lowest spot, and before it can flow back the sun's heat has reclaimed it for the atmosphere.

The Lake-bottom is now covered with a wiry form of grass, with a marsh-loving buttercup, and with several plants allied to the saltbush. These latter flourish in the saline soil, and are much relished by sheep after they become used to the new food. The saline flora is a new importation, I was assured. The Lake is now portioned into grazing leases, and fences run nearly across the bed. The local sheep-breeders for the most part much prefer the Lake dry, since many extra sheep can be carried on their runs. Water of a very pure type can be obtained almost anywhere along the western shore, at a depth of 12 to 30 feet, and several wind-mills are now engaged in raising it to elevated tanks for distribution. At the same time the neglected boathouses, jetties, and decaying boats and launches which are to be seen near Bungendore, recall the good old times when the Lake teemed with Murray cod, to be replaced later by carp; and when black duck and other game were in the habit of frequenting the huge sheet of water.

Lately arrived foreigners, in the shape of foxes and rabbits, are hardly calculated to equal the old fauna from an economic point of view.

From 1828 to 1864, the Lake was only for one year (1852) more than ten feet deep, so that the indications seem to point rather to a continuance of the present arid conditions, so far as one is able to judge from records not yet extending over a century.

The graph (fig.4) is drawn from that given in Russell's paper (quoted above), and brought up to date from information given me by Mr. Glover, who keeps an official record of the meteorology of Lake George.

## vi. Age of the Subsidence.

Mr. Russell made use of Lake George as a *gigantic rain-gauge*, and, from the data he obtained, he put forward some very interesting theories as to weather cycles and their causes. It has occurred to me that Lake George may serve as a *geological chronometer* for much the same reason, that it "keeps all it gets," whether water or silt. The foregoing sections will demonstrate the reasonability of stating that Lake George probably never had an outlet. Hence the *silt* deposited in Lake George should give us some idea of the time which has elapsed since the extensive faulting instanced took place.

All the data made use of are open to criticism, but it is hoped that the method used may be of interest, and that the result may represent a period of years of the right *order* if not correct to a few hundred units.

From Russell's textbook on Rivers* I obtained the following figures for the silt-deposits of the River Po in North Italy; and corresponding numbers for Lake George are tabulated alongside.

Table i.

| | | River Po. | Lake George. |
|---|---|---|---|
| A. | Area of Basin ... ... | 30,000 sq. m. | 300 sq. m. |
| B. | Rainfall (H.R.Mill) ... | 30 inches p.a. | 25 inches. |
| C. | Ratio $\frac{\text{silt}}{\text{water}}$ ... ... | $\frac{1}{900}$ | $\frac{1}{2000}$ |
| D. | Silt deposited per annum | 67 million tons. | $\frac{\text{3,400 mill. tons.}}{x \text{ years.}}$ |

A. (Area) gives the amount of material to be acted on.
B. (Rainfall) gives the effective eroding agent.

* River-Development. By I. C. Russell, 1898, pp.74-5.

C. (Ratio silt/water) varies with the different rivers from 1 in 2000 to 1 in 900. The former value would double the period in years, and is perhaps more nearly correct as the Po drains a *glaciated* country covered with débris.

D. The silt in Lake George was supposed to occupy a wedge 10 miles long, 5 miles wide, with base 100 feet deep. (This is probably too small a bulk). This gives a volume of 68,500 million cubic feet. Since a cubic foot of sand weighs about 100 lbs., this represents a weight of 3,400 million tons as deposited during a period of $x$ years.

As the area in question is $\frac{1}{100}$ of that drained by the river Po, and the rainfall and silt-carrying power less for Lake George, we may roughly put down $\frac{67,000,000 \times 25 \times 900}{100 \times 30 \times 2000}$ as the amount deposited in Lake George in one year ($=250,000$ tons).

Hence 3,400 million tons will be deposited in $\frac{3,400,000,000}{250,000}$ years, or say roughly 14,000 years; a result which is quite as near the truth as could be expected. No account has been taken of the velocity-factor, which is very important in connection with silt-carriage. If the velocity were lower than the mean velocity of the Po, it would increase the period. If the rainfall, as is probable, were heavier in prehistoric times in Australia, it would decrease the period. However, one may perhaps be permitted to set down this huge senkungsfeld as having taken place less than twenty thousand years ago.

## vii. Summary.

Lake George, the largest lake in New South Wales, occupies an area of subsidence (*senkungsfeld*) bounded on the west by a fault plane of about 400 feet drop. The fault is approximately parallel to the strike of the Palæozoic slates and phyllites. It runs north and south for thirty miles, and constitutes the Cullarin Range. The violent tectonic changes have entirely altered the drainage-system of the district. The Molonglo flows through a gorge it has cut in the Cullarin Range, and is clearly an antecedent river. The feeders of Lake George once formed part of the Yass River system. Their lower portions are buried under the silt of Lake George, and they thus fall into the class of betrunked rivers. The old outlet (Old Lake George River) can be traced as a series of elevated river-gravels for three miles towards the Yass River. The boulders, some over two feet in length, cap hills nearly 300 feet above the present level of the lake-bed. The economic aspects of the senkungsfeld in connection with elevated auriferous alluvials, and the pastoral claims on the lake-bed are traced out.

From a comparison with the known silt-forming capacity of the basin of the River Po in Italy, an attempt is made to give a time-value to the silt-contents of Lake George. A period of less than twenty thousand years is shown to be sufficient to fill up the lake basin to its present silt-level under modern conditions. Hence the fault and senkungsfeld may be referred to a period contemporaneous with the close of the Great Ice Age in the northern hemisphere, and probably to the period during which the Blue Mountain folding at Lapstone Hill took place in New South Wales.

## Part ii. Lake Bathurst.

### 1. General Physiography.

This Lake lies about twelve miles to the east of Lake George, on the further side of the Cooma railway line, which approaches within a mile of the lake near Tarago (see fig.5 and stereogram, Plate viii.). It is roughly triangular in outline, with the base to the east. Quartzite hills about 200 feet high border the east and south-west sides, while an area of granite extends into the lake-bed on the north-west, forming a long reef connecting Rabbit Island to the bluffs of the surrounding hills.

At each corner is an area of low-lying land. To the north-east a low bank separates the lake from the Bonnie Doon Morass. At periods of flood the two areas form one sheet of water. The southern corner receives the main feeder of the lake, known locally as Chain o' Ponds. Here is a considerable extent of gravels. At the western corner of the lake the gap between the hills is filled in with another extensive deposit of gravels which has been tapped by a railway siding for ballast purposes. When full, the Lake has an area of five square miles, and is thus very much smaller than Lake George.

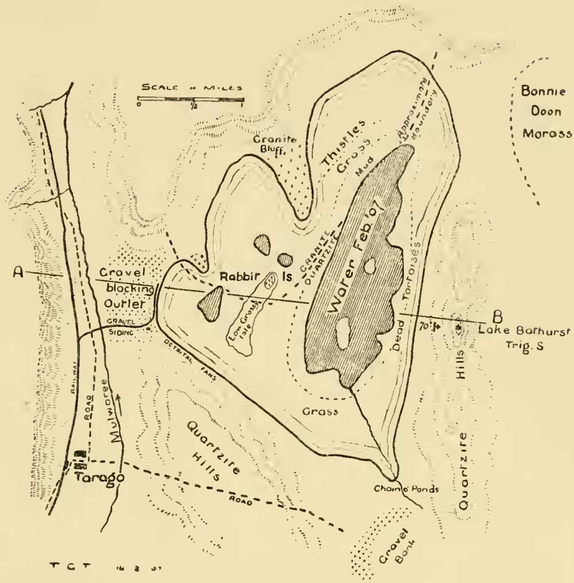


Fig.5.—Map of Lake Bathurst showing its physiography (Feb., 1907). The boundary between the granite and quartzite is indicated approximately.

During February, 1907, I made a careful survey of the Lake, for the purpose of determining the area covered by water, and the character of the dam to which the lake owed its origin.

Leaving the road and approaching the Lake from the south, one reached a zone of coarse quartzose sand with subangular fragments of quartzite, evidently derived from the neighbouring hills. Then came a zone of grey sticky mud about 200 yards wide, and finally the water was reached. This was very brackish and covered with a slight scum. The mud gave off a musty smell, recalling that of certain guano reefs, and was possibly due to the same cause, since a flock of gulls were swimming in the northern portion of the lake. Journeying eastward across the Chain o'

Ponds, one traversed a sandy mud with occasional flat-growing, fleshy weeds. The coarse grass at the foot of Lake Bathurst Trig. Station was littered with dead tortoises. One passed three or four every yard, mostly about a foot long. These reptiles were driven out of the lake in the autumn of 1906 by the increasing salinity, and as there is no permanent water on the eastern shore, perished. In some such manner, no doubt, many of the huge deposits of vertebrates found fossil in various parts of the world took their origin. From the Trig. Station a fine view of the lake basin and surroundings is obtainable (fig.7). Rabbit Island is a prominent feature, large wattle-trees growing amid the huge granite blocks which have determined the island. The well-defined gap to the south-west at the gravel-siding shows up as the lowest portion of the lip of the basin.

Continuing along the north-east shore, granite outcrops are met with, their position being shown on the map. At this northern end is the deepest part of the Lake, about one foot deep in February, 1907. Prominent bluffs of granite occur on the north-west shore. Completing the traverse by way of Rabbit Island (which is now merely a mound in a thinly grassed paddock), a series of *detrital fans* is crossed. These bear witness to the vigour of the torrents rushing down the hillsides, and have a bearing on the origin of the Lake.

Not many years ago sculling matches took place on the Lake between Rabbit Island and the gravel-siding, which latter was also used to convey passengers to the recreation ground on the edge of the lake. With the drying of the lake, the attraction of the recreation ground has passed; and the pavilion, a prominent and useful landmark, has now degenerated into a stable.

Referring to the section across Lake Bathurst (fig.6), the geological features near the gravel-siding can be made out. About half-a-mile to the west of the lake, the Mulwaree Creek flows to join the Wollondilly-Hawkesbury system at Goulburn. This stream rises about ten miles south of the Lake, and drains a fairly large basin. Between Tarago and the Lake-outlet, the valley contracts so that the stream flows at the foot of rather steep quartzite ridges, about 300 feet high. These ridges are covered with a loose talus which is continually dropping into the

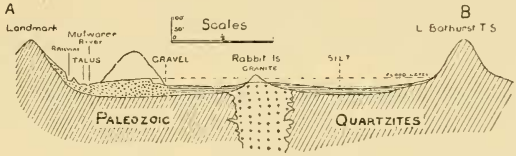


Fig. 6.—Section A B (see fig. 4) across Lake Bathurst, showing the gravel-dam across the outlet and the *talus* occupying the Mulwaree Valley.

creek. In the railway cuttings 30 feet or more of this talus (mingled with soil) are evident.

The explanation of the lake-origin which I venture to put forward is intimately connected with this abundance of talus in the narrow valley of the Mulwaree.

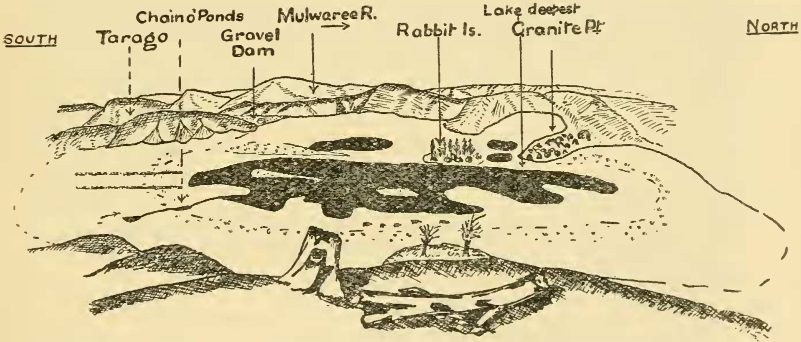


Fig. 7.—Sketch view of Lake Bathurst from the top of the Trig. Station on the eastern shore. The black area indicates the extent of water in February, 1907. When filled, the Lake covers the whole flat expanse.

## ii. Origin of Lake Bathurst.

In earlier geological periods, possibly when a somewhat greater rainfall obtained in New South Wales, the Mulwaree Creek received a pair of tributaries from the east. One of these drained the valley now occupied by the Bonnie Doon Lagoon (N.E.), and the other held much the same position as the Chain o' Ponds (S.E.) does now. These creeks crossed the bed of Lake Bathurst, and entered Mulwaree Creek near the gravel-siding.

During periods of drought, these lesser lateral streams would probably cease flowing, and their entrance into the main creek, not being scoured by any current, would very readily be choked by material washed down by the parent stream and derived from hills in the immediate vicinity.

Thus would arise a shallow lake which, given periods of increasing aridity, would serve as a settling ground for the water poured in by the two small tributaries postulated above.

Talus and pebbles brought down into this youthful lake would be rolled about by the storms (which are still a feature of the lake when flooded) and piled in the angles, giving rise to the gravel mentioned as occupying those positions. Each succeeding period of flood would but serve to isolate the lake more and more, by enabling further material to be piled on the barrier, which would also be strengthened by the talus distributed by the Mulwaree Creek on the outer face of the dam.*

Given conditions of increasing aridity, a main stream flowing through a narrow talus-covered gorge, and a lateral valley of circumscribed cross-section receiving the drainage of a much smaller area; these, I believe, constitute the factors which have led to the isolation of Lake Bathurst.

In conclusion, a few dates in connection with Lake Bathurst may be noted.

1844. Lake Bathurst dry.

1870-8. A "banker," as in Lake George.

1873. The Lake overflowed into the Mulwaree over the gravel-siding.

1890. The lake rose to the lower rails of the siding. Within a few feet of overflow. Goulburn residents anxious as to danger of flood if the gravel-dam burst.

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* Readers of the National Geographic Magazine will recall the origin of the Salton Sink in California, due to damming up of a lateral valley by silt carried down by the Colorado River.

1907. One-quarter of the bed covered, not more than one foot deep in the larger area.

From these dates one can see that the floods in Lakes George and Bathurst agree sufficiently closely. Their modes of origin are, however, entirely dissimilar, Lake Bathurst being merely a dammed-up river valley, while Lake George is an example of a huge senkungsfeld and fault-scarp which has absolutely altered all the original drainage-scheme of the area comprised in its basin.

In conclusion, I desire to thank Messrs. J. Barrett (Tarago), Gill (Winderadeen), Glover (Bungendore), and Donelly (Douglas) for much help received while carrying out my investigations on Lakes Bathurst and George.

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## EXPLANATION OF PLATES.

### Plate vii.

Map of the Lake George "Senkungsfeld" and Fault Scarp (Cullarin Range). The granite area is only approximate. The high-level gravels (making the old outlet) are indicated to scale as black oval patches. The extent of water in February, 1907, is shown by the hatched area on the east of the lake.

### Plate viii.

Stereogram of Lake George showing the area of internal drainage. The high-level gravels, south of Geary's Gap, are marked. The antecedent valley of the Molonglo appears at the lower end. In the north-east the main features of the Lake Bathurst area are indicated.

### Plate ix.

A view of the Lake-bed in February, 1907. The Lake has been practically dry for four or five years, and is sparsely covered with a nutritious salt-bush on which the sheep may be observed to be feeding.

### Plate x.

From a photo taken in 1884 when the Lake was nearly full of water. The irregular eastern coastline culminating in Governor's Hill (to the right) appears in the background.